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QUARTERMASTER RESEARCH & ENGINEERING COMMAND
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TECHNICAL REPORT
EP-155

EFFECT OF CLOTHING COLOR ON SOLAR HEAT LOAD

QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

JUNE 1961

NATICK, MASSACHUSETTS

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Quartermaster Research & Engineering Center, Natick, Mass.
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2. Climatic factors
3. Clothing
4. Desert tests
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J. R. Breckenridge R. L. Pratt

BIOPHYSICS BRANCH

Project Reference:
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FOREWORD

When air temperature is high, any additional heat load upon the soldier becomes quite important. The heating effect of sunlight, or solar heat load, represents such a heat load, particularly in the tropics where cooling by sweat evaporation is limited. There is a higher potential for sweat evaporation in the desert, but solar heat nevertheless is undesirable since it reduces the activity level which can be maintained without undue physiological strain. Minimal solar heat load consistent with other requirements is obviously essential to maintain the soldier's efficiency at a high level in hot environments.

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ABSTRACT

Solar heat loads on seated subjects, wearing hot-weather uniforms in various colors, were determined during a series of 30 three-hour experiments in the desert near Yuma, Arizona. Black and white uniforms were compared during one summer, green and khaki during the next. The conclusions were derived from sweat evaporation data in sun and shade, assuming that evaporative heat loss equaled the total heat load.

The calculated solar heat loads were 145 kg-cal/hr and 92 kg-cal/hr for black and white uniforms, and 113 kg-cal/hr and 92 kg-cal/hr for green and khaki. In terms of the total heat load on the man, the differences with color represented increases of only 17% for black over white, and 7% for green over khaki. The white uniform had much less advantage than fabric reflectance measurements would indicate, possibly because multiple reflections in the vicinity of folds and creases increased the amount of radiation absorbed.

EFFECT OF CLOTHING COLOR ON SOLAR HEAT LOAD*

1. Introduction

The average individual associates light-colored clothing with a feeling of coolness in summer. This has some basis in fact since lighter shades reflect more of the sun's rays (4) and are cooler to the touch. Civilian summer wear is rather thin and much of the radiant energy absorbed by the fabric appears as a heat load at the skin surface. Hence one might, by applying civilian experience, conclude that the physiological effects of color should not be overlooked in the design of a hot-weather uniform. Such a conclusion places the designer in the difficult position of satisfying color requirements for both environmental protection and camouflage, which requirements are often at variance with one another.

The present study was conducted to determine how much the heat stress caused by sunlight is affected by the shade and color of typical hot-weather uniforms. Pratt (6) found that the heating effect of sunlight on fabric-covered flat plates was not closely related to their absorption characteristics. In one instance, more heat was produced under a thick, cream-colored pile material than under one colored dark brown. This was explained by assuming that the lighter-colored fibers reflected a considerable amount of radiation into the pile, where it would have more effect on the plate than a like amount absorbed near the outside fabric surface (2). Presumably the dark pile absorbed more radiation, but it did not penetrate as deeply and thus was less efficient. Such spectacular results were not anticipated with the fabrics used in hot-weather uniforms, which are relatively thin and tightly woven.** However, it seemed likely that such reflection effects might greatly reduce the importance of color as a factor in heat stress, possibly to the point where it could be neglected.

Two experiments were conducted at Yuma Test Station, Yuma, Arizona, during the summer months of two consecutive years. Information on the effect of color was obtained from physiological data on a group of subjects exposed in the sun wearing similar but differently-colored hot-weather ensembles. Actual solar heat loads in this typical desert environment were also calculated using other subjects simultaneously exposed in the shade to provide baseline data, as Adolph did in 1937 (1).

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*In this paper, "solar heat load" is defined in terms of the net heating effect produced at the <u>skin surface</u> by absorption of solar energy. This is a much more useful concept than defining solar heat load as the amount of radiation absorbed, since this is only remotely related to the effect on the man.

**Aldrich (5) has found little evidence of direct transmission through such fabrics but this is not proof that radiation scattering into and through a fabric does not occur. Only that fraction which passed undeflected through the fabric would be measured as transmission.

2. Methods

a. Uniforms studied

Two differently-colored but otherwise similar uniforms were compared during each summer. The ensembles used during both years were similarly designed and consisted of bush coat, field trousers, and cap. Those used in experiment I (the first year) were made of 6-oz poplin, white or dyed black. The experiment II (the next year) uniforms were experimental hot-wet and hot-dry types, also of 6-oz poplin, in green and khaki, respectively. These items were supplemented by cotton undershirt and shorts, wool socks, and desert boots with saran insoles.

b. Test site

The subjects were exposed in an open, level area best described as a sand and gravel flat, with a compacted surface and little vegetation. Part of the site was shaded with two spaced tarpaulins suspended one above the other, the lower about 10 feet above the ground. This arrangement kept the lower tarpaulin at about air temperature and prevented excessive long-wave radiation from reaching the subjects beneath it. Weather instrumentation and an observer tent were located nearby. A general view of the site showing the location and position of the subjects appears in Figure 1.

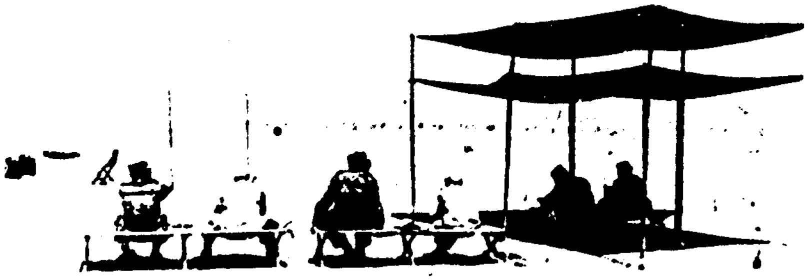

Figure 1. Typical experiment using green and khaki uniforms. (Note the darkness of subjects in shade, showing large reduction in solar illumination)

c. How solar heat load was determined

Solar heat load with each color was determined by comparing the total heat loads on subjects in the sun with those on subjects in the shade. These loads were derived directly from sweat evaporation data, assuming that no change in body heat content occurred, so that evaporative heat dissipation equaled total heat load.

d. Exposure periods and schedule of uniforms and positions

Six young, white, acclimatized soldiers were exposed for 3-hour periods, two in each color in the sun and one in each color in the shade. Twelve exposures were made in experiment I (black and white uniforms), 18 in experiment II (green and khaki uniforms) the next year. The subjects sat in a line on the sides of canvas cots, leaning slightly forward with the sun on their backs. Sweat secretion and evaporation were determined from nude and clothed weights, before and after exposure, and net water intake. The color worn and position (sun or shade) for each subject was determined from the schedule given in Table I.

TABLE I

SCHEDULE OF UNIFORMS AND SUBJECT POSITIONS

(Uniform colors denoted A and B)

Day \ Subject	1	2	3	4	5	6
1	A	A	B	A*	B*	B
2	A*	B	B*	A	B	A
3	A	B*	B	B	A	A*
4	B	B	A	B*	A*	A
5	B*	A	A*	B	A	B
6	B	A*	A	A	B	B*

*Subject in shade

This 6-day schedule, designed to minimize effects of subjective differences and daily weather changes, was followed twice in experiment I (i.e., 12 days) using the same subject assignments throughout. In experiment II which consisted of three 6-day series, the subjects were rearranged between series to change the pairings in the shade (a morale measure).

Experiments postponed or terminated because of excessive cloudiness (less than 80% normal sunlight) were run the following day.

e. Exposure procedure

In a typical exposure, nude and clothed weights were obtained (within ±10 grams), then the exposure was begun at about 1300 hours. Clothing was adjusted the same for all subjects, with coats buttoned and sleeves rolled down, and trouser cuffs rolled to the ankle. The bush coats were worn without belts, since these could not easily be adjusted for the same fit at the waist. The subjects were allowed to read and write but were not allowed to assume any extreme positions or shift about excessively. Water intake was measured but not restricted; in fact, subjects were encouraged to drink enough to replace evaporative losses. Necessary urination was done with the subject standing in place. The experiment was concluded by reweighing, recording subjective comments, and measuring water intake (net). Each subject later rinsed his uniform in water to remove accumulated salts, etc.

3. Controls in estimating solar heat load

Accurate estimation of solar heat load required careful control of such factors as thermal balance and mode of sweat evaporation, and of the factors affecting the various means of heat exchange.

a. Thermal balance of subjects

Evaporative heat dissipation at the skin is a measure of heat load *if* there is no change in the average body temperature. In experiment I no special precautions were taken to insure equilibrium; rectal and skin temperatures measured with standard catheters and 11-point thermocouple harnesses showed that mean weighted body temperature (Burton (3)) fell by less than 0.2F° per exposure. The next year, in experiment II, efforts were made to eliminate even this small change in body temperature by restricting the subjects to their tents for one-half hour before initial weighings; this kept them from engaging in heavy activity and minimized changes in thermal state during an experiment.

b. Mode of sweat evaporation

Sweat evaporation data cannot be converted into heat dissipation at the skin unless the sweat is evaporated as it is secreted. Otherwise it wets the clothing and is only partly effective when evaporated (2). The low air vapor pressure at Yuma was conducive to immediate evaporation and the skin generally remained dry. Minimal metabolic load decreased the chance for sweat accumulation, which was one reason for specifying a sitting position. The results will show that some accumulation occurred, but this was found in sockgear and unventilated areas (armpits, crotch) where

wetting of the clothing is not particularly important, since there is little evaporation from these areas.

c. Equalization precautions

Using total heat load as a basis for estimating the effect of sunlight is of course not valid unless metabolic heat production and factors affecting heat exchange with the environment are the same for all subjects. Body size (height, weight, and surface area) is obviously important since it influences the metabolic, convective, and thermal radiative loads, as well as the amount of sunlight received. The statistical exposure pattern followed was intended to average out the effects of individual differences. However, in experiment II, further refinement was sought by using selected subjects with similar heights, weights, and builds. This increased the chances of fitting the subjects alike and minimized differences in the heat and moisture transfer characteristics of their clothing.

Degree of acclimatization was eliminated as a factor by continuously controlling the subjects. After initial conditioning at the site for one week, they lived in tents, used outdoor facilities, and were under numerous restrictions (no alcohol, trips to town, etc.) except during scheduled rest periods. Rest periods were followed by one day of reconditioning before resuming the studies.

It was assumed that the shade tarpaulins did not affect any of the environmental factors (i.e., that they were the same for the subjects in sun and shade) except solar radiation. Air movement was probably not reduced by the tarpaulin since it was several feet from the subjects. Mean radiant temperature of the surroundings may have been different for the shaded subjects than for those in the open, although the difference was probably small. The ground temperature under the tarpaulin was lower than in the open but, to counterbalance this, the temperature of the lower tarpaulin was higher than sky temperature.

Other factors influencing the metabolic and environmental loads were largely standardized by placing all subjects in the same position relative to the surroundings and by supervising their movements and postures to minimize departures from the standards prescribed.

d. Corrections for reflected sunlight on shaded subjects

It was impossible to shield the shaded subjects against reflected sunlight from surrounding areas. A method was therefore developed for estimating its effect so that a correction factor could be derived. Two 6-inch globe thermometers (7) were hung at a 4-ft height near the subjects in both sun and shade; one was painted flat black and the other flat white. The globes at each location absorbed different percentages of the solar radiation incident on them but responded similarly to all other environmental loads. Temperatures of the globes were recorded with thermocouples

at 30-minute intervals during 10 of the experiment II exposures. The relative effect of solar radiation on a shaded globe was then calculated using the expression:

$$\frac{S}{S'} = \frac{T_B - T_W}{T_B' - T_W'}$$

where
S = Solar radiation load on a globe in the shade
T_B = Shade temperature of black globe
T_W = Shade temperature of white globe

and S' , T_B' , T_W' are the corresponding values in direct sunlight.

This equation is derived in the Appendix.

4. Results

a. Sweat evaporation data

The average amounts of sweat evaporated per 3-hour period are given in Table II for each color, in sun and shade. These were obtained by averaging the respective daily results. Similar data on sweat secretion are also included to show how little remained unevaporated.

TABLE II

AVERAGE SWEAT SECRETION AND EVAPORATION

(kg/man/3 hrs)

	Subjects in Sun			Subjects in Shade		
Color of Uniform	Secreted	Evap.	Unevap.	Secreted	Evap.	Unevap.
			Experiment I			
Black	2.167	1.930	0.237	1.464	1.273	0.191
White	1.864	1.651	0.213	1.412	1.236	0.176
Difference		0.279			0.037	
			Experiment II			
Green	1.812	1.651	0.161	1.273	1.141	0.132
Khaki	1.712	1.541	0.171	1.266	1.127	0.139
Difference		0.110			0.014	

In the sun, sweat evaporation averaged 279 grams more in black than in white uniforms, and 110 grams more in green than in khaki uniforms. Analysis of variance showed a significant difference at the 1% level for black vs white, and at the 5% level for green vs khaki. The differences in the shade were small (not significant), as might be expected.

Unevaporated sweat was higher in each instance in experiment I than in the comparable case in experiment II, but percentagewise it was practically constant for all colors at about 10% of secretion. As noted earlier, most of this accumulated in sockgear and in unventilated areas. The remainder of the sweat was evaporated from the skin and will be considered 100% efficient in cooling the body. Some of this was actually moisture evaporated from the lungs and mucous membranes, but this need not be differentiated, since it has the same effect as evaporation from the skin (same latent heat per gram evaporated).

b. Method of calculating solar heat load

Solar heat load was calculated as follows:

(1) The increased evaporation in the sun (that is, the amount more than in the shade) was converted to the equivalent heat dissipation (kg-cal per 3 hours). For the conversion, a latent heat of vaporization of 0.577 kg-cal/gm (the value for water at 35°C) was used.

(2) This equivalent heat dissipation was corrected for solar radiation reflected onto the shaded subjects. The factor used was obtained directly from the evaporation data, assuming that a color difference would have an effect proportional to the solar radiation load. In the shade, the differences in evaporation between black and white, and between green and khaki, were 13% of the differences in the sun. It was therefore assumed that the shaded subjects had a solar heat load on them which was 13% of that on the subjects in the sun. The additional evaporation in the sun in each color therefore represented only 87% (100% minus 13%) of the actual solar heat load and the results were corrected accordingly. (A correction factor was also derived from globe thermometer data but the value appeared to be high.*)

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*The globe thermometer data indicated a value almost twice as high, but this was due to poor placement of the globes. Hanging the globes at head level (4-ft height) placed them above center with respect to the subjects. As a result, the shaded globes were exposed to more reflected radiation than the subjects below them. This radiation in effect comes from a hemisphere with a radius equal to the average height above ground at which the object receiving radiation is located. The hemisphere for the globe is larger and therefore has a smaller percentage of its surface shaded by the tarpaulins. When corrections were made to account for this discrepancy, a value of 13.6% radiation on the shaded subjects was obtained, in substantial agreement with the value from evaporation data.

The corrected 3-hour results and solar heat loads (kg-cal/hr) are given in Table III.

TABLE III

CALCULATION OF SOLAR HEAT LOADS

Uniform Color	Increased Evap. in Sun* (grams)	Equiv. Heat Dissipation** (corrected) (kg-cal)	Solar Heat Load*** (kg-cal/hr)
Experiment I			
Black	657	436	145
White	415	275	92
Difference			53
Experiment II			
Green	510	338	113
Khaki	414	275	92
Difference			21

*Difference between values for sun and for shade.

**Value in column 1 was converted (X 0.577 kg-cal/gm) and the result corrected by dividing by 0.87.

***One-third of previous column, since data were for 3-hour period.

The difference between solar heat loads with black and white uniforms is 53 kg-cal/hr, which is relatively small considering the extremes of color and fabric reflectivity being compared. For a man with 1.8 square meters surface area, this is only about 30 kg-cal/m^2/hr, approximately equal to the difference between the heat production of sitting and standing men. Evaporative heat losses in the sun were only about 17% higher in the black uniform than in the white (Table II). This percentage difference is a maximum where activity is low and would be reduced as activity (metabolism) increased. Solar loads with green and khaki, more typical military colors, were only 21 kg-cal/hr different (7% difference in evaporative losses), leading to the conclusion that for hot-weather uniforms of the type studied color is a relatively unimportant physiological consideration.

5. Discussion

The reader is reminded that the solar heat loads were obtained under the wind conditions occurring at Yuma during this study (hourly averages ranged from 4 to 14 mph). In windier conditions the solar heat load could be expected to be lower, while under calm conditions it could be appreciably higher (6). Color may have some real effect on the acceptability of a uniform. However, questionnaires administered to the subjects in

experiment II failed to show any preference for the lighter-colored khaki uniform; in fact, the subjects apparently felt no hotter in the green than in the khaki uniform.

a. Relation of solar heat load to visible radiation absorbed

The solar heat loads are in the expected order but not closely related to the amount of visible radiation absorbed (determined from reflectance measurements on fabric samples in each color). Results on the white uniform are especially interesting, since the solar heat load is about 3 times as high as the reflectivity measurements would indicate. The white fabric absorbs only 15% as much radiation as the black does (average reflectances in the range 400 to 700 millimicrons were 85% and 2%, respectively) but the solar heat load in white was 63% of that in black. This apparently is the result of three effects which occur with a highly reflective fabric.

(1) Reflections from surface fibers to fibers nearer the skin make the radiation more efficient.

(2) White fabrics are more translucent than black and therefore more solar radiation is absorbed by the skin where it is 100% efficient.

(3) In clothing, some reflected radiation does not immediately escape but strikes other fabric surfaces where another portion is absorbed. This can occur in the vicinity of folds and creases, or between facing surfaces. Thus, the white fabric functions as a "grey", with a lower reflectance than measurements on a flat sample would indicate (9). Multiple reflections and translucence would be reduced with darker shades and be practically non-existent with black.

b. Heating efficiency considerations

Evidence to support this hypothesis is obtained by considering the heating efficiency of the radiation absorbed. For a sitting man in a hot-weather uniform, the effective area receiving sunlight is about 0.37 m^2 (8). Assuming an incident radiation at Yuma of 900 kg-cal/m^2/hr (1.5 langleys), the clothing receives 333 kg-cal/hr from direct sunlight. To this must be added radiation reflected from the ground which, based on the globe thermometer data, appears to be about 120 kg-cal/hr. Thus, the total radiant energy load at the clothing surface is about 450 kg-cal/hr.

The black uniform absorbed about 98%, or 440 kg-cal/hr. This radiation produced a solar heat load of 145 kg-cal/hr and was therefore 33% efficient. This value implies that the insulation from clothing surface to skin was twice that of the air layer outside the clothing (2).

Similar calculations for the white uniform, based on the measured reflectance of 85%, indicates an efficiency of 135%. Obviously less than 85% was reflected since one cannot assume more than 100% effectiveness of

absorbed radiation. An efficiency higher than 33% (as with black) is expected, with 100% as the upper limit, which places the reflectance for the white uniform between 47% and 80%.

The actual values of reflectance and efficiency are unimportant but it cannot be too strongly stressed that highly reflective fibers are not as advantageous as they appear. Khaki fabric was as effective as white, and green only slightly less so even though their measured reflectances are much lower. The white uniform was studied a year earlier, but this comparison is justified since solar radiation was essentially the same during both summers.

In conclusion, these findings corroborate the postulate made by Pratt (6) that color of clothing is not nearly as important with regard to solar heat load as is commonly assumed.

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APPENDIX

DERIVATION OF GLOBE THERMOMETER EQUATION FOR ESTIMATING SOLAR HEAT LOAD IN SHADE

The equation for the heat balance of an unheated globe receiving sunlight may be written:

$$A(S) = k(T - T_a) + R(T - T_r)$$

where A = the absorption coefficient of globe for solar radiation
S = sunlight falling on globe (direct plus reflected)
k = convective heat transfer coefficient
R = coefficient of long-wave radiation exchange with surroundings
T = globe temperature
T_a = air temperature
T_r = mean radiant temperature of surroundings

Taking the absorption coefficients of a black and a white globe in the shade as B and W, respectively, and subtracting the equation for the white globe from the equation for the black:

$$(B - W)S = k(T_B - T_W) + R(T_B - T_W)$$

where subscripts B and W refer to the black and white globe, respectively.

A similar equation may be written for the pair of globes in the sun. Then, dividing the equation for the shaded globes by that for those in the sun, we obtain:

$$\frac{(B - W)S}{(B - W)S'} = \frac{(k + R)(T_B - T_W)}{(k + R)(T_B' - T_W')}$$

or, assuming B, W, k and R to be independent of globe location:

$$\frac{S}{S'} = \frac{T_B - T_W}{T_B' - T_W'}$$

where the prime markings refer to the exposed globes. The factor $\frac{S}{S'}$ is the desired ratio of reflected sunlight on the shaded globes to reflected plus incident sunlight on the exposed globes.

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ARMY (Cont)

1 Commanding Officer
Signal Corps Engr. Lab.
Ft. Monmouth, N. J.

1 Office of Chief of Engineers
Department of the Army
Temp. Bldg. T-7, Gravelly Point
Washington 25, D. C.
Attn: Research & Dev. Div.

4 CO, Chemical Warfare Laboratories
Army Chemical Center, Maryland
Attn: Technical (AS 13) Library

1 Chief Chemical Officer
Department of the Army
Bldg. T-7, Gravelly Point
Washington 25, D. C.
Attn: Res. & Dev. Div.

2 CO, Hq., Medical Nutrition Lab.
Fitzsimons Army Hospital
Denver, Colorado
(1-Dr. Friedmann)

1 Armed Forces Institute of Pathology
Washington 25, D. C.

1 Chief, Armed Services Medical
Procurement Agency
84 Sands St., Brooklyn 1, N. Y.
Attn: Property Officer
Marked: Req. DUED #151

1 Chief of Transportation
Department of the Army
Temp Bldg. T-7, Gravelly Point
Washington 25, D. C.

2 Commanding Officer
Transportation Res & Eng Command
U. S. Army
Ft. Eustis, Virginia
Attn: Tech Services Dir.

1 The Army Library
Pentagon Bldg.,
Washington 25, D. C.

1 Commandant, Command & General Staff
College
Ft. Leavenworth, Kansas

1 Commandant, U. S. Military Academy
West Point, New York

1 Commanding Officer, Detroit Arsenal
28251 Van Dyke St., Centerline, Mich.
Attn: Res & Engr. Div.

1 Commanding General
Hqs., U.S. Army Medical R&D Command
Main Navy Bldg.
Washington 25, D. C.
Attn: NP&PP Research Branch

2 Commander
QM Intelligence Agency, U.S. Army
Washington 25, D. C.

2 Executive Director
Military Clothing and Textile Supply Agency
2800 S. 20th St., Phila. 45, Pa.

1 Commanding Officer
QM R&E Field Evaluation Agency, U.S. Army
Airborne Systems Test Div.
Yuma Test Station
Yuma, Arizona

ARMY (Cont)

1 Commanding Officer
Cold Weather & Mountain Indoctrination
School
Fort Greeley, Alaska

1 Commanding Officer
Fort Greeley, Alaska
Attn: Post Library

AIR FORCE

2 Department of Air Force
Hqs., USAF, Wash 25, D. C.
(1 DC/S Material, 1 DC/S Dev.)

1 Director
Air University Library. Attn: 7575
Maxwell AFB, Alabama

2 Commandant
USAF School of Aviation Medicine
Randolph AF Base
Randolph Field, Texas

1 Commander, Arctic Aeromedical Lab
APO 731, Seattle, Washington

1 Commander
Air Res & Dev Command
Attn: RDSBTL (Hqs., Tech Lib. Br.)
Andrews AF Base, Washington 25, D.C.

1 Commander
Wright Air Development Center
Wright Patterson AF Base, Ohio
Attn: Tech Library

1 Commander
Strategic Air Command
Offutt AF Base, Nebraska

1 Chief, Nutrition Div.
Air Development Center
Aero-Medical Lab.
Wright Patterson AFB, Ohio
Attn: Dr. Harry C. Dyme

1 Commander
AF Cambridge Research Center
Air Research & Development Cmd.
Laurence G. Hanscom Field
Bedford, Mass.
Attn: CRTOTT-2

NAVY

1 Director
Naval Research Laboratory
4th & Chesapeake St., S. W.
Washington 25, D. C.

1 Chief, Bureau of Ordnance
Department of the Navy
Washington 25, D. C.
Attn: R&D Div.

1 Naval Medical Research Institute
National Naval Med. Res. Center
Bethesda, Md.

2 Chief of Naval Research
Washington 25, D. C.
Attn: Code 4025

1 Chief, Bureau of Ships
Department of the Navy
Washington 25, D. C.
Attn: Code 331

1 Chief, Bureau of Med. & Surgery
Dept. of the Navy, Wash 25, D. C.
Attn: Code 33

NAVY (Cont)

1 Commander, U. S. Naval Ord. Test
Station, China Lake, Calif.
Attn: Code 753

1 Chief, Bureau of Aeronautics
Dept. of the Navy, Wash 25, D. C.
Attn: Code AE 52

1 Chief, Bureau of Supplies & Accounts
Department of the Navy
Washington 25, D. C.

CONARC

1 C.G., U.S. Continental Army Command
Ft. Monroe, Va.

1 President
U. S. Army Artillery Bd.
Ft. Sill, Okla.
Attn: ATBA

1 President
US Army Armor Board
Ft. Knox, Ky.
Attn: ATBB

1 President
U. S. Army Infantry Bd.
Ft. Benning, Ga.
Attn: ATBC

1 President
U. S. Army Air Defense Bd.
Ft. Bliss, Texas
Attn: ATBD

1 President
U. S. Army Airborne and Electronics Bd.
Ft. Bragg, N. C.
Attn: ATBF

1 President
U. S. Army Aviation Bd.
Ft. Rucker, Ala.
Attn: ATBG

1 Commanding Officer
U. S. Army Arctic Test Board
Ft. Greely, Alaska
Attn: ATBE

BOARDS & COMMITTEES

1 Army Committee on Environment
Chief, Research & Development
Pentagon, Washington, D. C.

1 Armed Forces Pest Control Bd.
Walter Reed Army Med. Center
Forest Glen Annex
Main Bldg.
Forest Glen, Maryland

1 Army Research Committee
Chief, Research & Development
Pentagon, Washington, D. C.

MISCELLANEOUS

1 National Research Council
2101 Constitution Ave., Washington, D.C.
Attn: Advisory Bd. on QM R&D

1 Armed Services Technical Information Agency
Arlington Hall Station
Arlington 12, Va.
Attn: TIPDR

4 Gift and Exchange Division
Library of Congress
Washington 25, D. C.

1 U. S. Department of Commerce
Weather Bureau Library, Washington, D.C.

1 Central Intelligence Agency
Collection & Dissemination
Washington 25, D. C.

1 National Library of Medicine
Washington 25, D. C.

1 [illegible]
[illegible]
[illegible]
Oslo, Norway

1 Marine Corps Equipment Board
Marine Development Center
Marine Corps School
Quantico, Va.

1 Office of Technical Services
U. S. Department of Commerce
Washington 25, D. C
Attn: Tech Rpts Sec (THRU OQMG)

1 U. S. Department of Agriculture Library
Washington 25, D. C.

1 Commandant
Industrial College of the Armed Forces
Ft. McNair, Washington 25, D. C.

1 QM Representative
Army Command and General Staff College
Department of the Infantry Div.
Ft. Leavenworth, Kansas